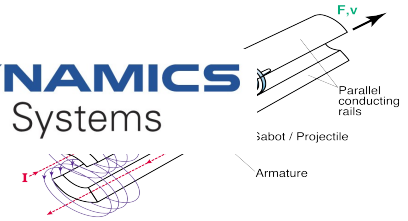
GENERAL DYNAMICS
Ordnance and Tactical Systems

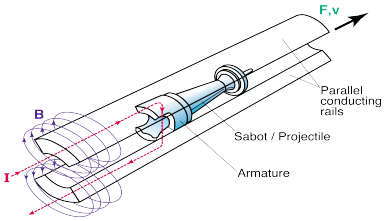


40th Annual Armament Systems: Guns, Ammo, Rockets, Missiles
April 25-28, New Orleans, LA

Development and Testing of High Explosive (HE) Projectiles for Electro-Magnetic Gun Army Tech Objective (ATO)

Manfredi Luciano
RDECOM-ARDEC
Picatinny, NJ

Army Program
First EM Technology Spiral



FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13

STO **ATD**

S Special ASARC

1 Full Scale Lethality vs Complex Targets Risk Reduced

IPR POM 08

2 Launcher Life Risk Reduced

3 **A** Energy Density Risk Reduced

4 Subsystem Thermal Management Risk Reduced

5 System Integration Risk Reduced

6.2 designs

Proposed Subsystem Designs

Subsystem Models

Full caliber tests

2-5MJ, 5000 kg, uncooled, unruggedized rectangular bore (60mm equiv) fully cantilevered unguided multipurpose & unguided KE rounds. unguided KE, terminal ballistics vs. Tank @ 8MJ ME level

Full firing chain @ 2-5MJ. Single Shot Externally supplied prime power

Burst firing chain. Integrated prime power. Lethality vs. BMPs, bunkers, buildings, personnel

2-5MJ, 5000 kg, cooled, ruggedized

2-5MJ muzzle energy LOS EM Gun system

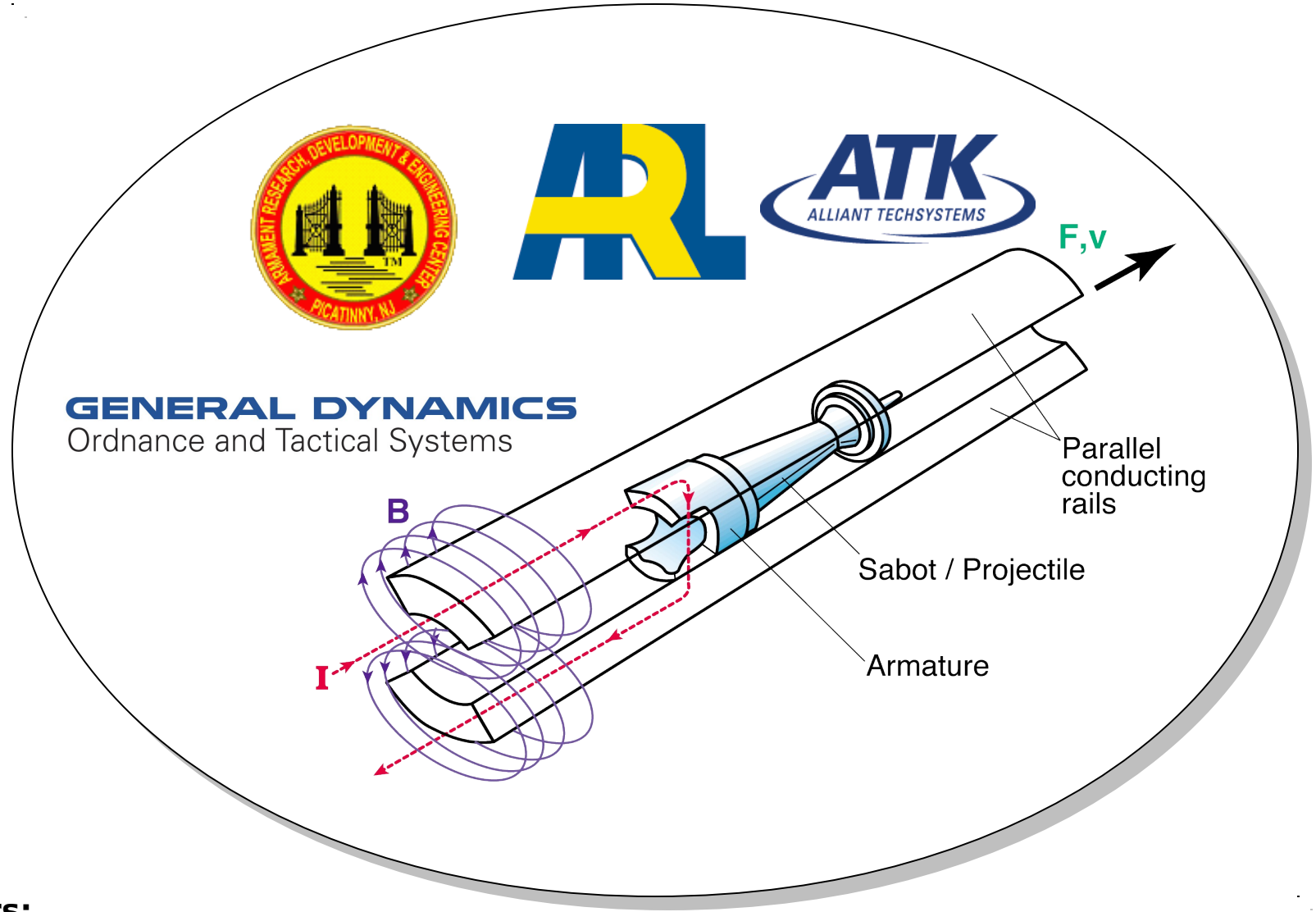
< 19 ton platform fires burst,

Perforates BMP @ 2km

Multi-burst operation

Special ASARC approved this ATD approach

Intra Army, Multi-Contractor Collaborative



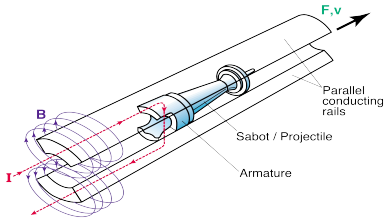
Authors:

ARDEC: Manfredi Luciano, David Okken, Vinod Nagori, Justin Rhodes, Robert Bryan, John Grau

ARL: Alex Zielinski

GD-OTS: Karl B. Linde, and ATK: Eric Quist

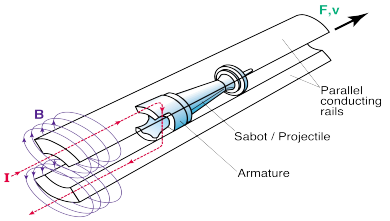
H.E. Integrated Launch Package (ILP) Feasibility Task

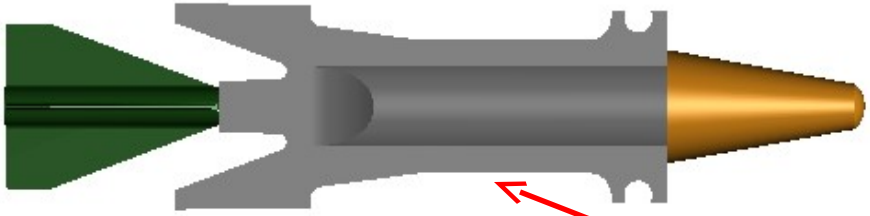


- **Objective:** Demonstrate HE ILP from EM Gun, Achieving TRL-5.
  - Integrate armature, flight body, fuze, & HE for a 2 km target demo

- **Approach**
  - Test from ARL ½ MJ Electro-Magnetic Gun
  - Task order contracts to GD-OTS & ATK for Hardware Mfg
  - Team intellectual collaborative effort
    - Maturing general EM technology
    - No competition between parties; non-tactical bullet
- **Concerns**
  - Can high explosive & fuze survive high current, high magnetic field environment?
  - Can large body, fin stabilized sub-projectiles be launched from high lateral load and high voltage environment?

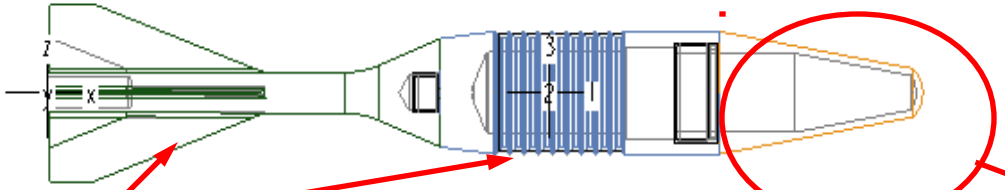
HE ILP Initial Design





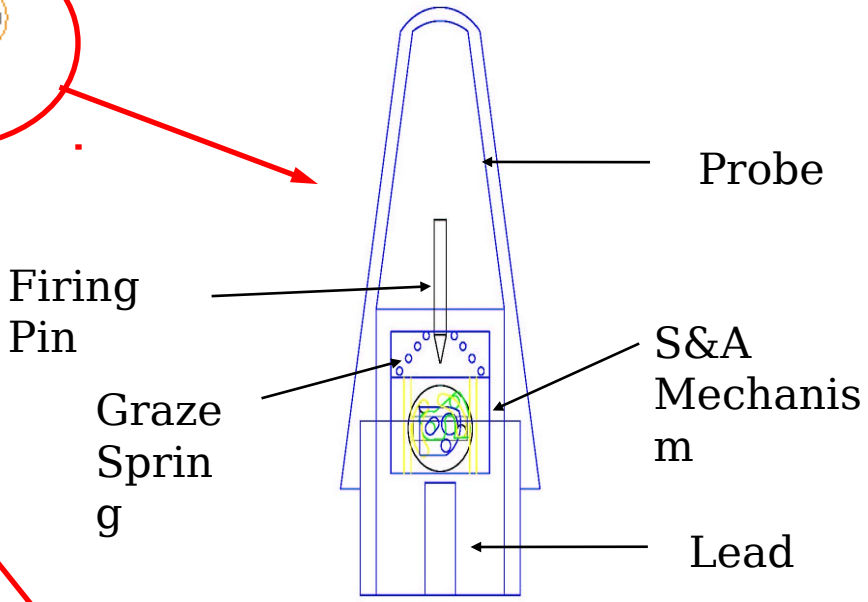
Integrated Launch Package:
Integrates Sup-Projectile, Sabot, & Armature

Armature for EM Launch



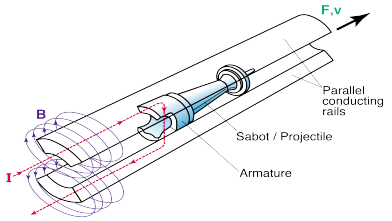
Body & H.E. Based on M792 (25mm HEI-T)

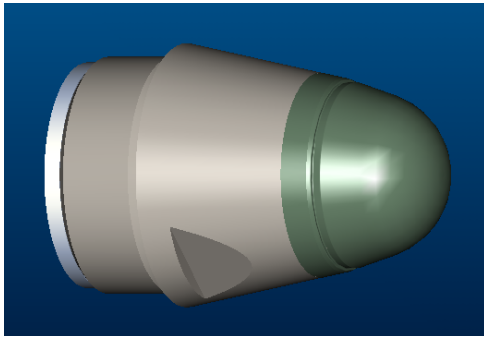
No Spin Environment
-Requires Boom/Fin for Stability
- Clipped Delta, Four Bladed
-Requires 2nd Fuze Arming Mechanism

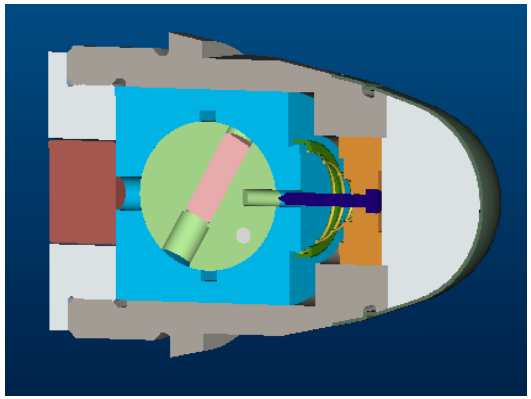


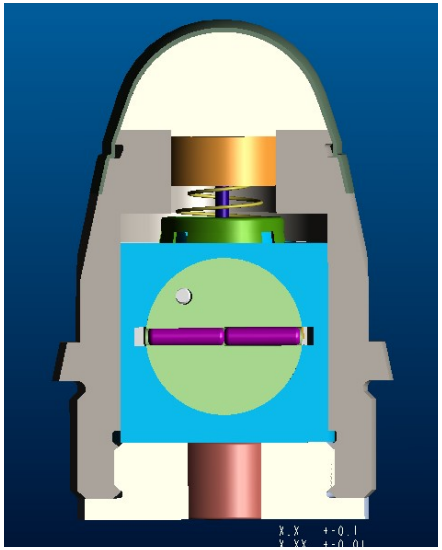
Dual Arm Fuze: Setback & EM

EM ILP Fuze Concept









Dual Arm:

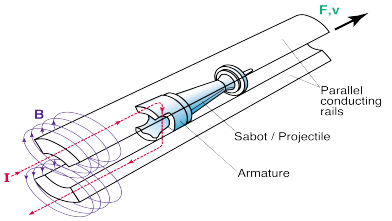
Setback Stab Plunger

Magnets Polarized from EM Field

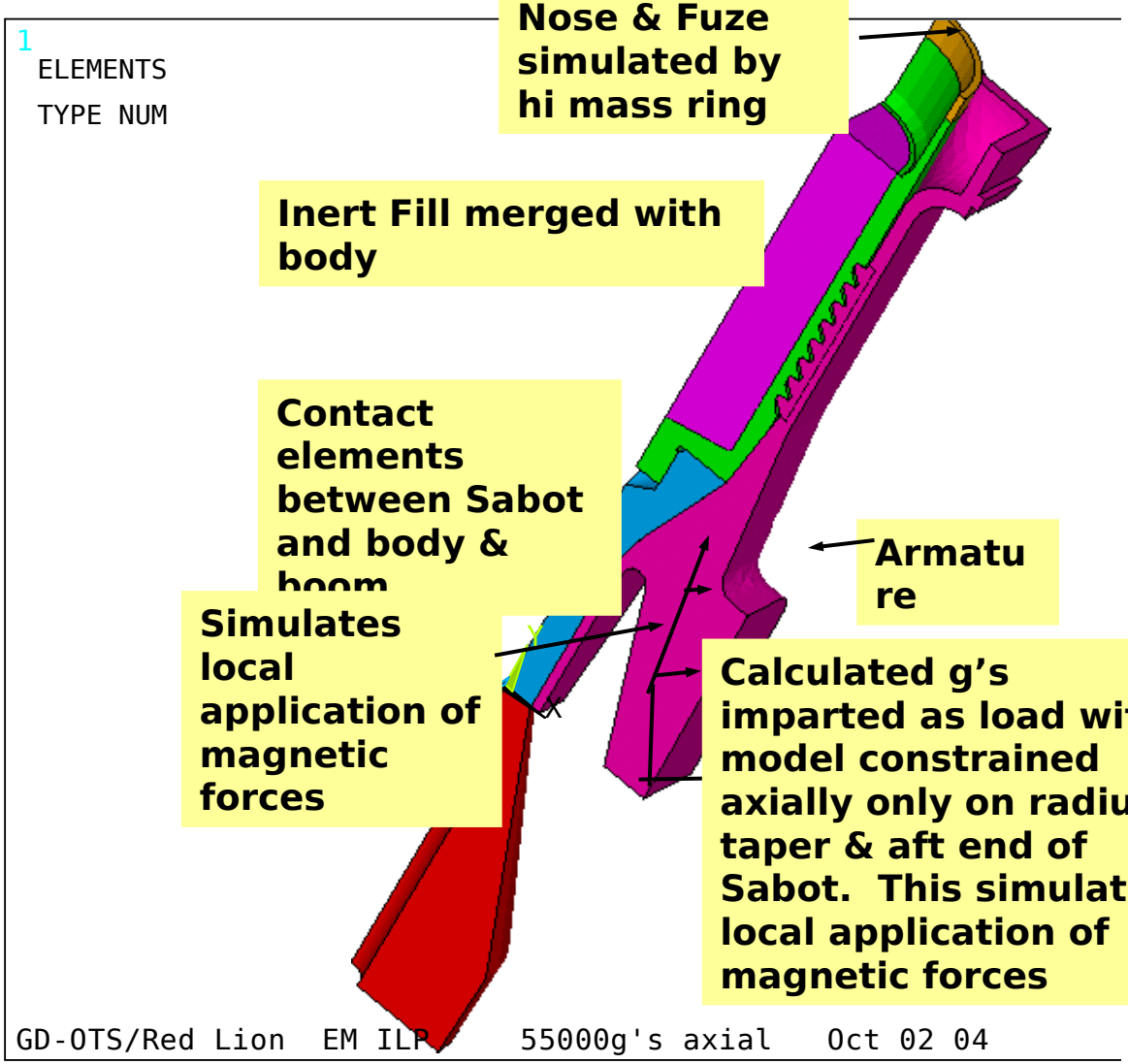
For More Info, see 49th Annual NDIA Fuze Conference Paper

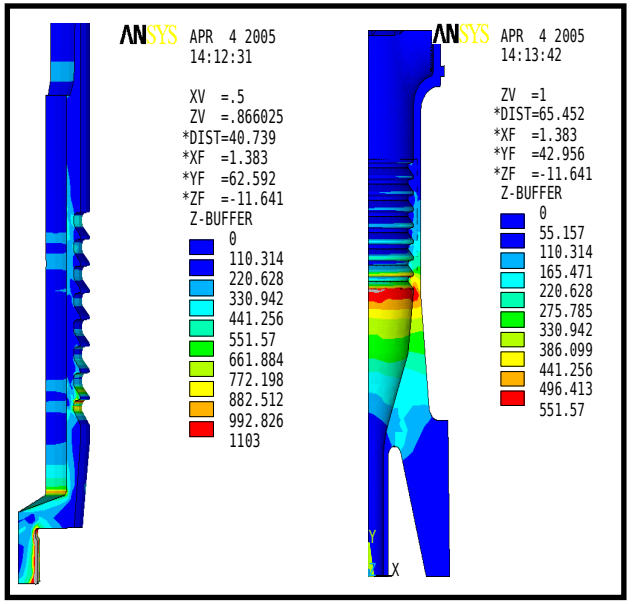
April 5 – 7, Seattle, WA

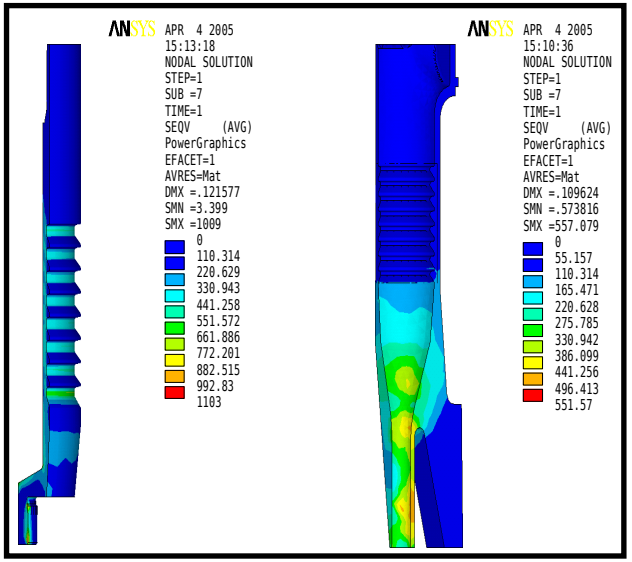
Modeling & Simulation - FEA



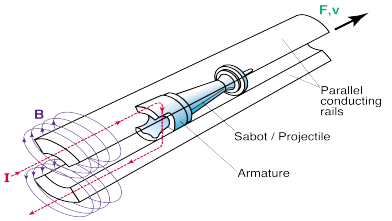
FEA Model

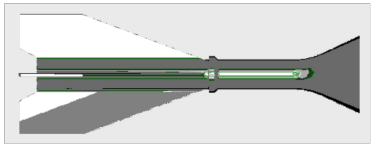

1
ELEMENTS
TYPE NUM
Nose & Fuze simulated by hi mass ring
Inert Fill merged with body
Contact elements between Sabot and body & boom
Armatu re
Simulates local application of magnetic forces
Calculated g's imparted as load with model constrained axially only on radius, taper & aft end of Sabot. This simulates local application of magnetic forces
GD-OTS/Red Lion EM ILP 55000g's axial Oct 02 04



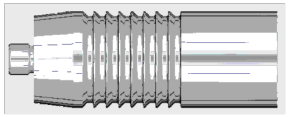


ILP Design & Assembly

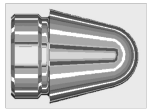




Fin/Boom
Mtl: Al 7075
Mass: .020kg

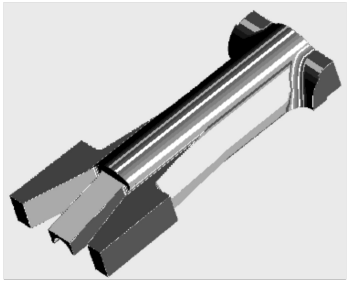


Body
Mtl: 4140Steel
Mass: .084kg
Inert HE. Fill .026kg

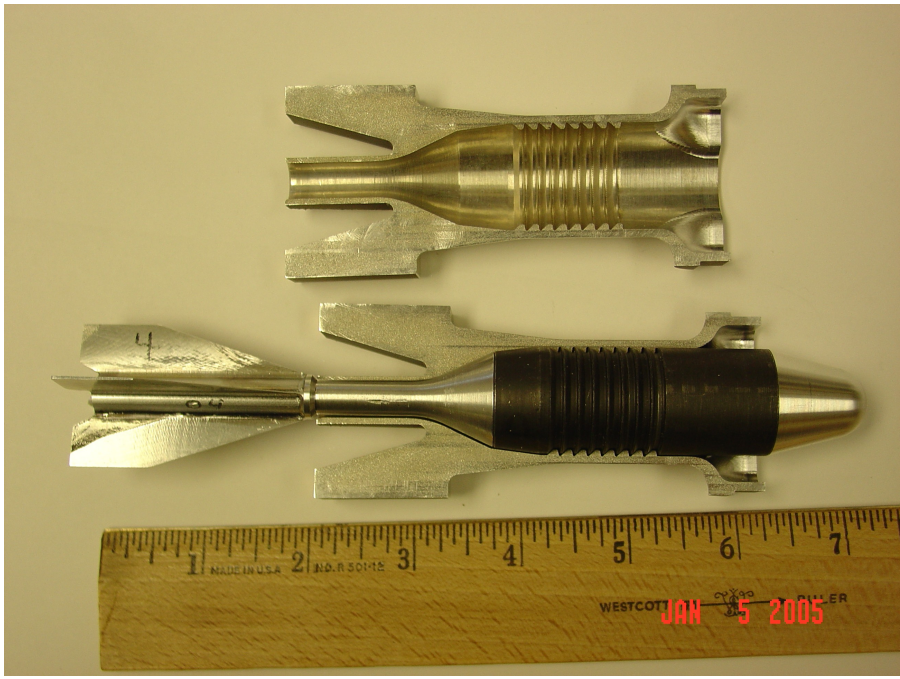


Dummy Nose
Mtl: Al 7075
Mass: .027kg

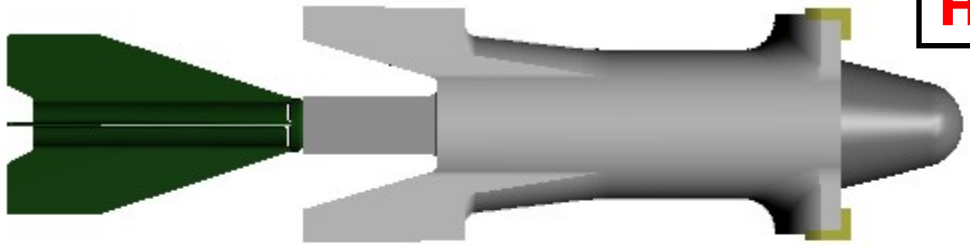
Bore Rider
Mtl: Nylon 42A
Mass: .001kg



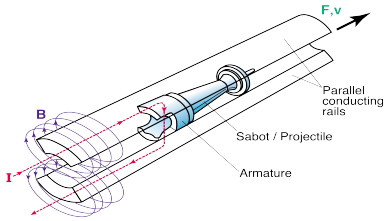
Sabot/Armature
Mtl: Al 7075
Mass: .106kg



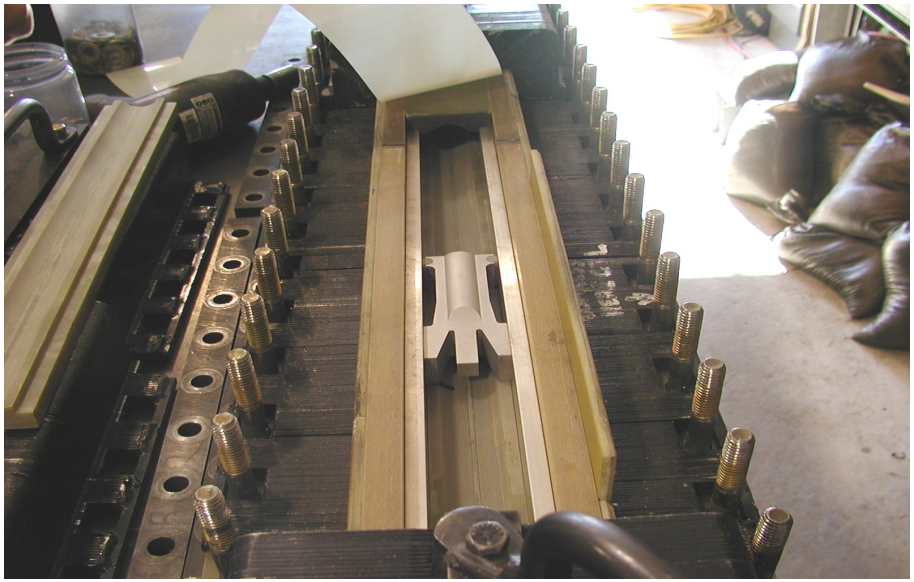
Actual Hardware



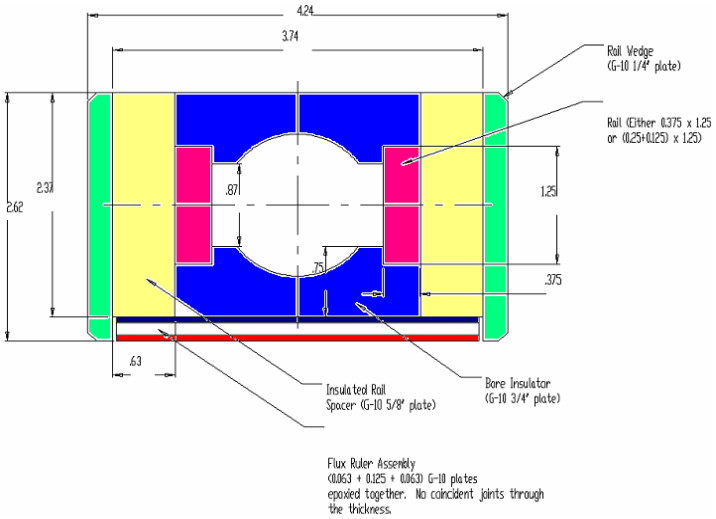
Test Vehicle - ARL ½ MJ EM-GUN

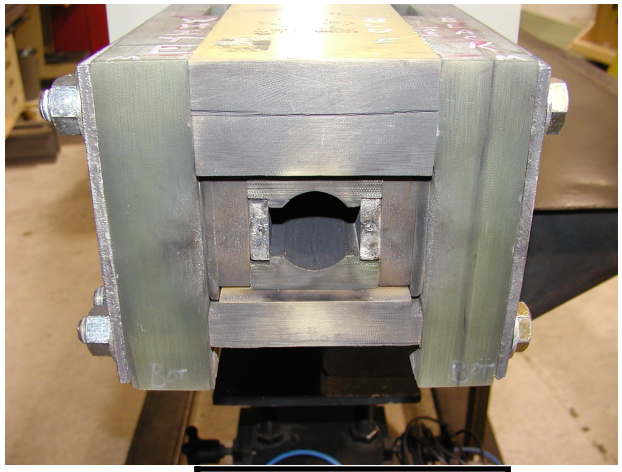


- **Max Muzzle Energy = ½ MJ**
- **Peak Current = 1MA**
- **Gun Length = 2.8 m**
- **Gun Cross Section = 22mm x 44 mm**
- **Scalloped Insulation Cross Section area = 38 mm (diameter)**
- **Rails replaced after each shot.**



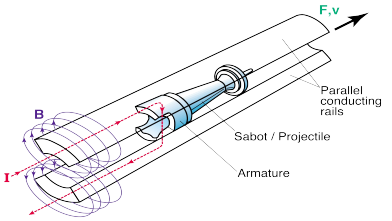
Test Launcher w/ Slug

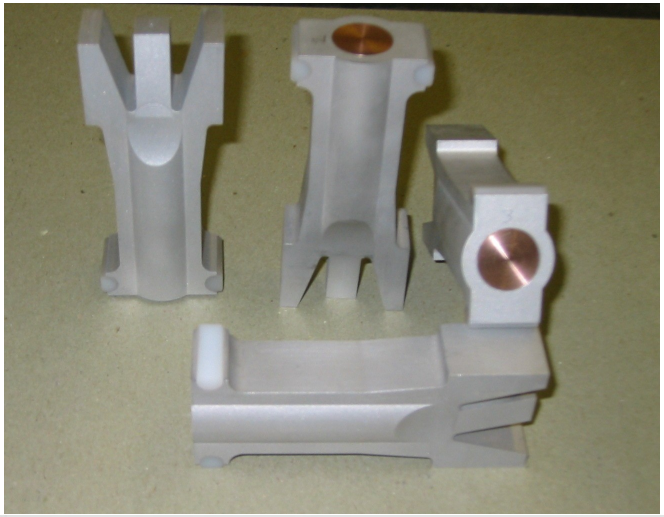




Muzzle View

Test Results - Slug Test



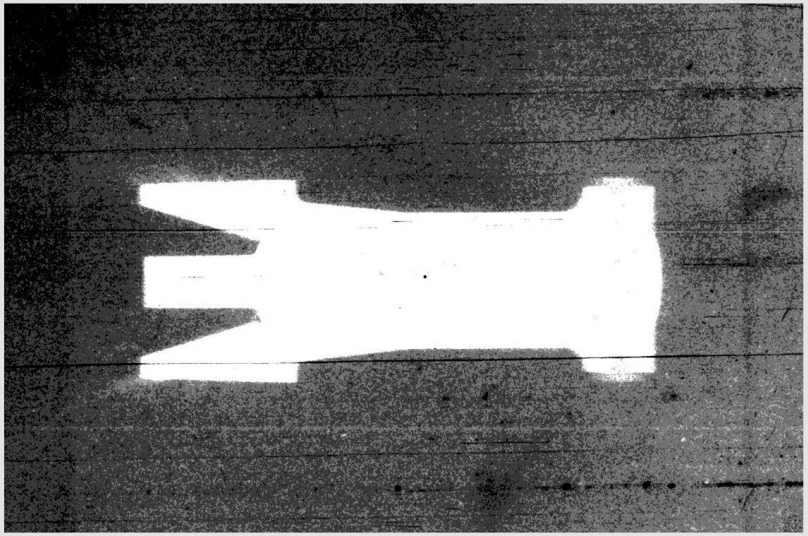


Objectives:

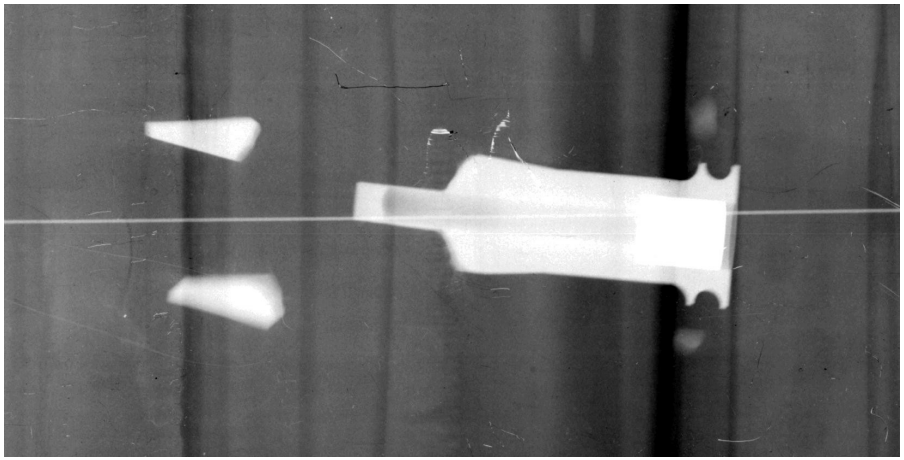
- **Verify Acceleration & Velocity**
- **Assess armature for current flow**

Ballistic Goals:

- **1200 m/s Muzzle Velocity**
- **276 gms Mass**

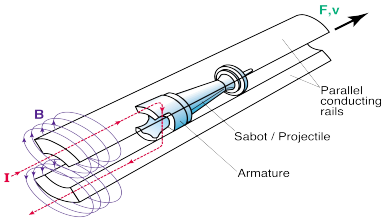


Shot One, Low



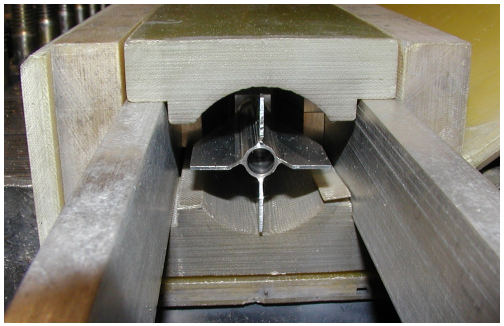
Shot Two, Higher

Test Results - ILP

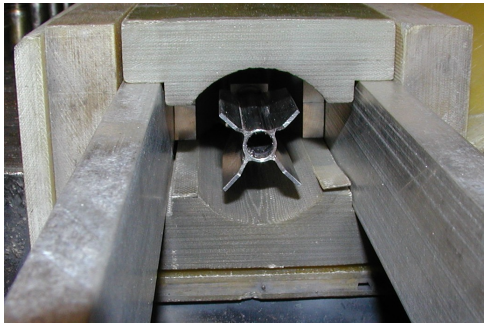


- **Six Projectiles tested**
  - **SOD test**
  - **Two fin orientations, 90 and 45 degrees**
- **Two out of six were successful**
- **Fin blades and hub failed seen**
- **Results seem to be a function of; Acceleration, Transition Current, and**

Fin Orientations

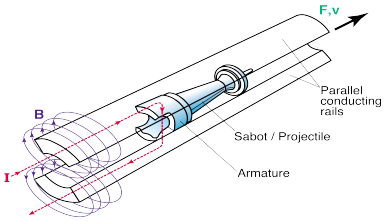


90º



45º

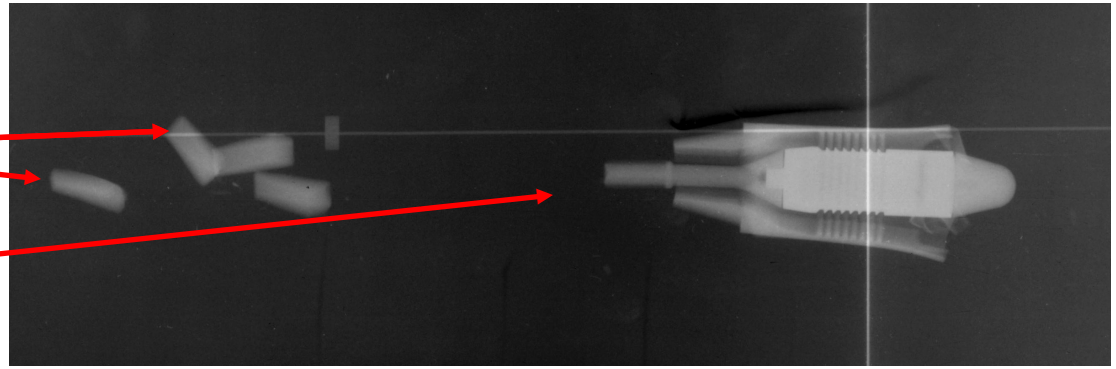
SOD Test X-Rays



X-Ray Picture 22” From Muzzle

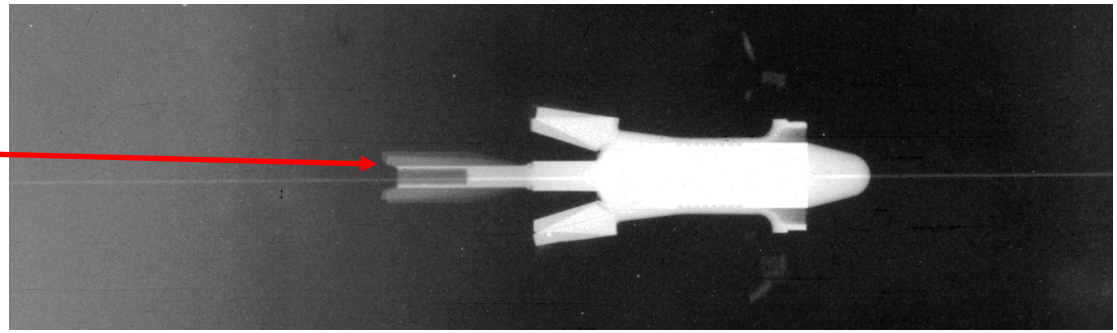
Shot # 1

- **Armature Legs Fractured On Muzzle Exit**
- **Fin Blades & Hub fractured**



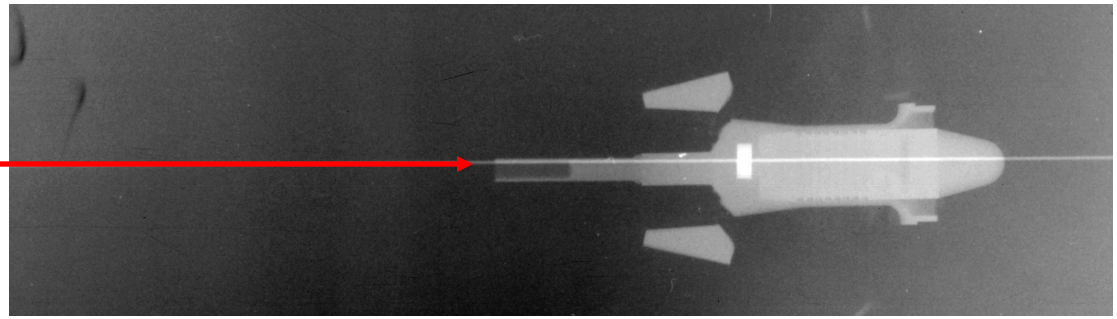
Shot # 3

- **Fins & Fin-Hub Intact**

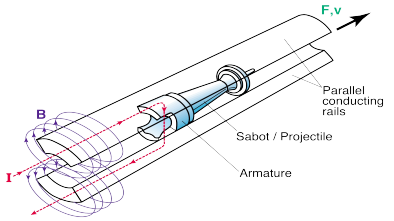


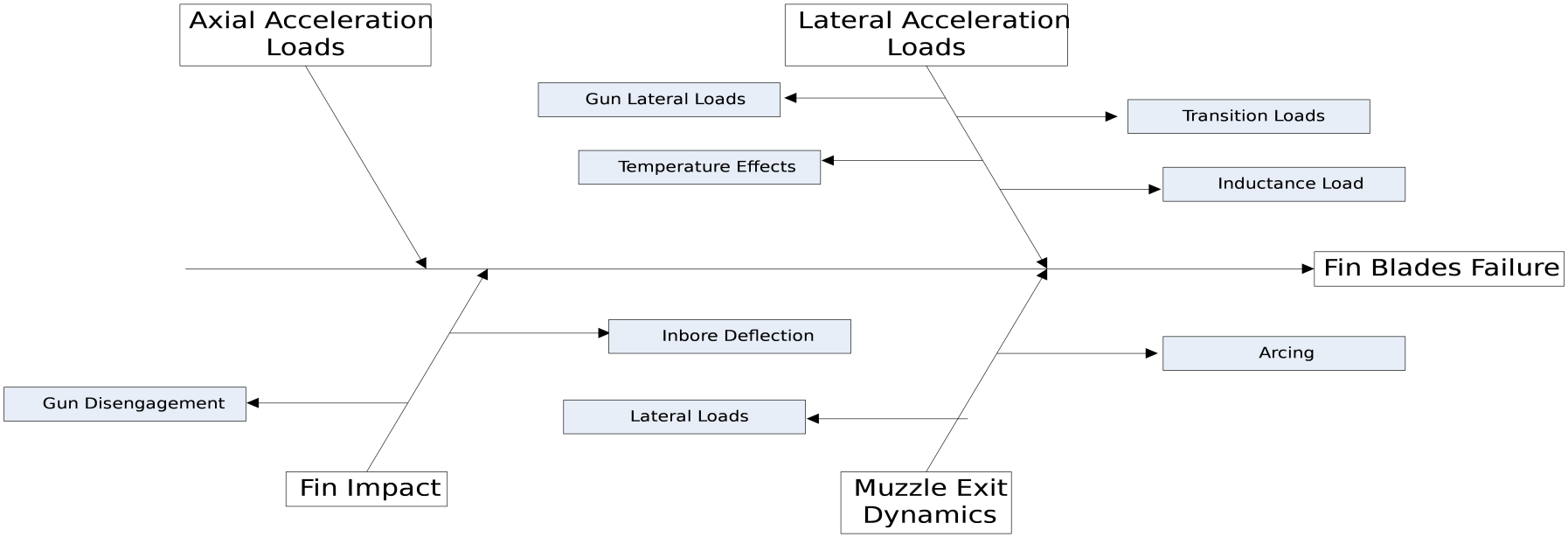
Shot #6

- **Fins Missing**
- **Fin-Hub Intact**



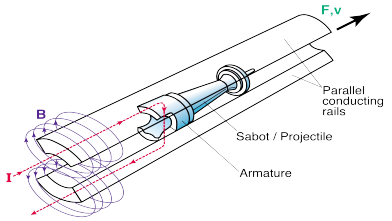
Failure Analysis





Root Cause Fishbone

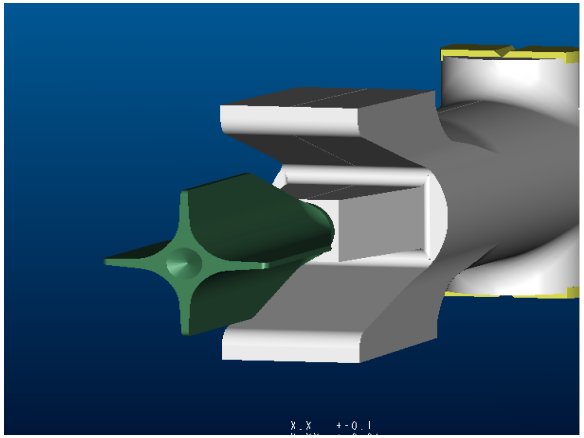
Go- Forward Plan



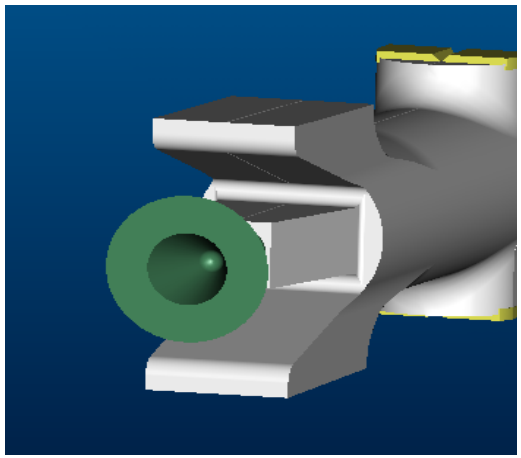
Next Test Series - May 2005

- To Minimize Muzzle Exit Effects:
  - Add muzzle shunt to gun
- To Minimize Transition Loads:
  - Increase armature length for increase rail surface contact
  - Increase Chevron thickness
- Two New Fin/Boom Designs, two materials each:
  A. Mod A – Increase Strength Four-Bladed Fin
  B. Mod B – Flare

Note: Fin designs are modular for quick changing at test.

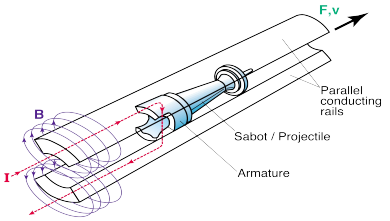


Mod A – Four-Bladed Fin



Mod B – Flare

Summary



- **Designed correctly for axial loads.**
  - **Design survived 62.8 KG's.**
- **Assumed & Designed for lateral loads at 20% of axial (11 KG's).**
- **Do we understand all lateral loads?**
- **Do we understand muzzle exit dynamics?**